Scientific Article

Bonding of Resin Composite to Caries-affected Dentin after Carisolv® Treatment

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Abstract: ***Purpose:*** *The purpose of this study was to investigate the effect of Carisolv® on resin composite adhesion on caries-affected dentin.* ***Methods:*** *Carious lesion specimens (N=46) were prepared from 45 extracted primary molars: Group 1 (N=23)—chemomechanical (Carisolv®) treatment; Group 2 (N=23)—rotary instrumentation; and Group 3 (N=23)—caries-free specimens from 20 noncarious primary molars. After caries removal (Groups 1 and 2) or washing and drying (Group 3), a resin composite rod (2-mm high, 0.975-mm diameter) was bonded vertically to dentin. Specimens were stressed at constant displacement (1.0 mm/minute) to failure; treated surfaces were examined under a scanning electron microscope.* ***Results:*** *The mean (±SD) microshear bond strengths of resin composite to dentin were: Group 1=6.69 (±4.08) MPa; Group 2=10.31 (±5.47) MPa; and Group 3=7.16 (±6.64) MPa. The mean bond strength of resin composite of Group 2 significantly exceeded that of Groups 1 (P=.02) and 3 (P=.01); Groups 1 and 3 did not differ significantly. There was no significant association between failure mode and treatment type (P=.22) or mean bond strength (P=.44). Carisolv® removed the smear layer or limited its formation, producing demineralization incompletely infiltrated by resin composite.* ***Conclusion:*** *Chemomechanical treatment of caries-affected dentin of primary teeth did not adversely affect resin composite bonding.* *(Pediatr Dent 2011;33:213-20) Received October 13, 2009 / Last Revision May 4, 2010 / Accepted May 10, 2010*

KEYWORDS: CHEMOMECHANICAL CARIES REMOVAL, MICROSHEAR BOND STRENGTH, DENTAL CAVITY PREPARATION

Chemomechanical caries removal with Carisolv® (Mediteam Dental AB, Sävedalen, Sweden) is a hand excavation technique using a lubricating gel that chemically alters infected carious dentin, mechanically aiding its removal.[1,2] Little is known of the bonding of resin composite to caries-affected dentin following Carisolv® treatment.

Carisolv® is marketed as a pink gel together with hand instruments and 2 syringes: 1 contains sodium hypochlorite (0.5%); the other contains 3 amino acids (glutamic acid, leucine, and lysine) in a carboxymethylcellulose gel and sodium chloride/sodium hydroxide solution at pH 11.[3] Caries removal is facilitated by the proteolytic action of sodium hypochlorite in removing organic components at room temperature. The amino acids enhance the effect of sodium hypochlorite and minimise collagen degradation, which can be remineralized.[4] The gel was modified recently to a clear formulation with a lower amino acid concentration and a higher sodium hypochlorite concentration (0.95%) than previously.

Carisolv® has been shown to have no adverse effects on pulp, healthy dentin, or oral mucosa in case of accidental contact.[5-11] Both in vitro and in vivo studies have shown effective and efficient caries removal.[1,12-17] The product has been indicated for caries removal in both primary and permanent teeth where preserving tooth structure is important, either alone or with rotary instrumentation, for access or to remove existing restorations.[4,18] Reports suggest caries removal with Carisolv® is preferable to conventional methods for children since the technique is quiet and vibration-free and does not require local anesthesia. Despite a longer working time, child behaviour was not affected adversely.[19-25]

Both the smear layer and the hybrid layer, formed from the interaction of resin bonding agents with the conditioned dentin surface, contribute to the bonding of adhesive restorative materials.[26,27] Resin penetration into the collagen network in the intertubular demineralized matrix enhances bonding. Most prepared dentinal surfaces show a smear layer 3- to 10-µm thick—an amorphous layer of organic and inorganic debris that firmly adheres to the surface and which cannot be removed by water spray. This prevents resin adhesion to dentin; to obtain adequate bonding, the smear layer must be removed or treated prior to resin placement by brief etching of the dentin surface.[26,27]

Therefore, it is important to consider the dentinal surface created during caries excavation. Banerjee et al., compared the dentinal surfaces following excavation by rotary and chemomechanical methods, using scanning electron microscopy (SEM).[1] Carisolv® produced a roughened, flaky surface with patent dentinal tubules and without an extensive smear layer, considered by the authors to be more conducive to adhesive bonding than surfaces produced by

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rotary methods. The lack of a smear layer following chemomechanical caries removal has been noted by others.[28,29] Other laboratory studies comparing prepared dentin surfaces of permanent teeth noted few patent orifices of dentinal tubules, however, suggesting that Carisolv® did not remove the smear layer.[30-33] The conflicting findings may depend on: whether the dentin was carious or noncarious; whether the carious dentin was soft, hard, infected, or arrested; the Carisolv® treatment time; and sample preparation.

Bonding to caries-affected dentin treated with Carisolv® is believed to produce lower bond strength than when bonding to noncarious dentin.[34] To date, studies evaluating the bond strength to dentin treated with Carisolv® or Caridex (MediTeam Dental AB, Sweden) systems concluded that chemomechanical caries removal had no adverse effect on bonding.[35] The shear bond strengths of 2 glass ionomer cements, bonded to dentin after caries removal with either Caridex® (with and without polyacrylic acid conditioning) or conventional methods (with polyacrylic acid conditioning), were studied in freshly extracted teeth.[35] The shear bond strength values following chemomechanical and conventional methods of caries removal were similar,[35] supporting the findings of others.[36,37]

Carisolv's effect on the shear bond strength of bonding systems applied with or without acid etching has been investigated. Haak et at., used extracted permanent molar teeth with occlusal caries with a minimum cavitation entrance of 1 mm and laser fluorescence (DIAGNODent) values exceeding 40.[37] Caries was removed conventionally in half the sample and chemomechanically (Carisolv®) in the other half. The caries removal method had no consistent effect on subsequent bond strength.[37] The teeth were stored in ethanol, however, which may stiffen collagen and alter the outcome of bond tests.[38,39]

Since primary and permanent teeth differ in dentinal hardness, mineral content, and micromorphology, and Carisolv®-treated surfaces may also differ in morphology, the effects of conditioning caries-affected dentin of primary and permanent teeth treated with Carisolv® and conventional instrumentation are also expected to differ.[40-42] Conditioning of primary tooth dentin with Carisolv® was more efficient than conditioning dentin from permanent teeth.[40] The chemomechanical treatment may overcondition, causing excessive demineralization, collapsed dentinal collagen, and inferior bonding.[40] When shear bond strength values of 3 dentin bonding systems were compared in noncarious primary and permanent dentin treated with Carisolv®, the values for primary teeth were significantly lower than for permanent teeth, with some variation according to the bonding system type.[40,43,44]

Little is known about the bonding of resin composite to caries-affected dentin after Carisolv® treatment. Laboratory reports have shown no differences in bond strengths of adhesive restorations between Carisolv®-treated and conventionally treated, caries-affected dentin in permanent teeth.[34-37,45,46] To date, only 1 study has investigated the shear bond strength of adhesive restorations to noncarious primary dentin treated with Carisolv®, showing significantly lower bond strengths than for adhesive restorations bonded to sound dentin.[39,43] No studies appear to have investigated this with reference to caries-affected dentin of primary teeth.

The purposes of this in vitro study were to: measure the shear bond strength of resin composite to caries-affected dentin of primary teeth treated with Carisolv® in comparison with rotary instrumentation; and examine the tooth/resin surfaces after testing bond strength.

Methods

Ethical approval for using extracted teeth was obtained (Human Research Ethics Committee, University of Melbourne, Melbourne, Victoria, Australia). Extracted carious (N=45) and noncarious (N=20) primary molars were obtained from children attending the Dental Department of the Royal Children's Hospital of Melbourne and stored in deionized water with 0.1% thymol. The carious lesions were moderate in size, extending into the dentin but not into the pulp of the tooth, as assessed during caries removal.

Tooth roots were removed perpendicular to the long axis of the tooth with a 0.3-mm thick diamond blade (Struers, Copenhagen, Denmark). The crowns were washed in distilled water and dried with a triplex syringe, and caries was identified visually and under magnification. Following caries removal (soon to be described), crowns with carious lesions were sectioned beneath the occlusal lesion, parallel to the occlusal plane, to provide a coronal sample. Each sample was then segmented vertically, in buccolingual and mesiodistal directions, to provide 4 segments (hereafter termed specimens). Specimens with caries extending more than halfway into dentin or extending into the pulp were excluded. One specimen per tooth was selected from each of 44 teeth, and 2 specimens were selected from 1 additional tooth (total=46 carious specimens).

In the caries-free group, the crowns were sectioned parallel to the occlusal plane to provide a coronal dentinal sample, and each sample was then segmented vertically, as aforementioned, into 4 specimens. One specimen per tooth was selected from each of 17 teeth, and 2 specimens were selected from each of 3 further teeth (total=23 caries-free specimens). Carious specimens were supported on green stick compound (Kerr GmbH, NSW, Australia), mounted on an acrylic base for convenient handling, and assigned randomly: Group 1 (N=23 specimens)—Carisolv® treatment; Group 2 (N=23)—rotary instrumentation; and Group 3—caries-free specimens (N=23).

In Group 1, caries was removed using clear Carisolv® gel (Mediteam Dental AB), a PowerDrive motor (Mediteam Dental AB), and the hand instruments provided, according to the manufacturer's directions. The gel was dispensed with a static mixer (Mediteam Dental AB) into a dappen dish, dispersed over the carious dentin with a spoon excavator, and left in place for 30 seconds. Carious dentin was removed gently using size 3 and 5 burs in the Power Drive motor and size-matched hand instruments. Debris-contaminated gel was removed with cotton pellets, and fresh gel was applied. The procedure was repeated until the gel was clear, caries removal was complete, and the dentin was hard on probing. Residual gel was removed with cotton pellets moistened with distilled water.

In Group 2, caries was removed using round steel burs (sizes 3 and 5) in a slow-speed handpiece. Caries removal was verified visually and tactually; the cavities were examined using magnifying loupes (2.5X) and probed to verify hard dentin. Rotary instrumentation was used for Groups 1 and 2 to match caries removal techniques.

In Group 3, the noncarious specimens were not polished to simulate the clinical situation. Obtaining control specimens from caries-free areas of teeth in Groups 1 and 2 for comparison was not possible due to insufficient caries-free areas.

All specimens were stored in 0.1% thymol in deionized water until preparation for bonding. Prepared specimens were examined to find a flat surface suitable for testing; this was placed in contact with a glass slide and attached with sticky wax (Associated Dental Products Ltd, Swindon, UK) around the specimen periphery. A plastic ring (internal diameter 15 mm) was placed over the specimen and filled with type III dental stone (Yellowstone, Gibling Stone, Thomastown, Victoria, Australia). When the stone was set, the glass slide and sticky wax were removed, providing a flat dentinal surface ready for bonding.

After dentinal etching with phosphoric acid, washing, and minimal drying, an adhesive dentinal bonding agent, 3M ESPE Single Bond (SB; 3M ESPE, St Paul, Minn), was applied to all prepared areas of specimens according to the manufacturer's directions. A PVC tube (internal diameter=0.97 mm, 2 mm high; Microtube Extensions, Sydney, NSW, Australia) was placed on the dentin surface and light-cured together with the adhesive. The tube was filled with resin composite (Filtek Supreme Universal Restorative; B2 Shade, batch no. 20030715, 3M ESPE) and light-cured for 40 seconds. The tube was removed with a no. 11 scalpel blade, leaving a 2-mm high resin composite rod (diameter= 0.97 mm) bonded perpendicularly to the dentin. All specimens were stored in tap water at 37°C for 12 hours prior to testing.

The bonded interface was subjected to microshear bond strength testing in an Instron machine (Instron, model no. 5544, Canton, Mass); a loop of ligature wire (Unitex, diameter 0.009 inches, TP Orthodontics, Leeds, UK) delivered a force parallel to the bonded surface at a crosshead speed of 1.0 mm/minute. The microshear bond strength value in megapascals (**MPa**) at fracture was calculated for each specimen using the formula:

$$\text{Microshear bond strength (MPa)} = \text{shear force (N)} / \text{cross-sectional area (mm}^2\text{)}$$

Fractured surfaces were examined under light microscopy (25X), and digital images were obtained. Failures were classified as: adhesive interface failure (100% of the bonded interface failed between dentin and bonding resin); cohesive dentinal failure (100% of the failure in dentin); cohesive resin failure (100% of failure in resin composite); or a mixed failure (partial cohesive failure and partial adhesive failure).

The images were studied, and representative specimens were selected for examination under SEM. Each specimen was retrieved from the plastic ring, air-dried for 2 days on filter paper, mounted on an aluminium stub with conductive silver liquid, gold sputter-coated, and examined using a field-emission scanning electron microscope (Philips XL 30 FEG, Eindhoven, The Netherlands).

Representative specimens from each group were selected to examine the interface. Shallow grooves were cut across the prepared dentinal surface using a high-speed tungsten carbide bur (no. 330, Jet, ISO no. 237001008, Beavers, Ontario, Canada) under water coolant, avoiding cutting the bonded interface. The specimens were then fractured by splitting vertically along the prepared grooves with a plastic instrument, rinsed under running water for 60 seconds, dried, and prepared for SEM examination, as aforementioned.

Descriptive statistics were prepared for microshear bond strength values for each group; group means were compared

Table 1. MEAN MICROSHEAR BOND STRENGTHS OF RESIN COMPOSITE TO PRIMARY TOOTH DENTIN FOLLOWING CARISOLV® TREATMENT OR ROTARY INSTRUMENTATION

Measure	Distribution of primary tooth dentin specimens		
	Group 1: Carisolv® treatment (N=23)	Group 2: Rotary instrumentation (N=23)	Group 3: Control (N=23)
No. of specimens that failed during preparation (%)	2 (9)	3 (13)	3 (13)
No. of specimens tested	21	20	20
Mean microshear bond strength (MPa) ±(SD)	6.69±4.08	10.31±5.47	7.16±6.64
Mean difference ±(SD):			
Group 1 vs Group 2		0.20±0.09; P=.02*†	
Group 2 vs Group 3		0.23±0.09; P=.01†	
Group 1 vs Group 3		0.02±0.00; P=.80‡	

* Fisher's exact test for comparison of means; statistical significance=P<.05.
† Considered statistically significant.
‡ Not considered statistically significant.

Table 2. DISTRIBUTION OF MODES OF FAILURE OF RESIN COMPOSITE BONDED TO PRIMARY TOOTH DENTIN FOLLOWING CARISOLV® TREATMENT OR ROTARY INSTRUMENTATION

Mode of failure	Distribution of primary tooth dentin specimens		
	Group 1: Carisolv® treatment (N=21)	Group 2: Rotary instrumentation (N=20)	Group 3: Control (N=20)
Adhesive (%)	6 (29)	6 (30)	12 (60)
Cohesive in dentin (%)	3 (14)	1 (5)	2 (10)
Cohesive in resin (%)	4 (19)	2 (10)	1 (5)
Mixed (partial cohesive and partial adhesive) failure (%)	8 (38)	11 (55)	5 (25)

using SPSS Graduate Pack V13.0 for Windows (SPSS Inc, Chicago, Ill). Assumptions of normality and equal variance were verified; logarithmic data transformation was performed to achieve normality, if necessary. A 1-way analysis of variance (**ANOVA**) comparison of means was performed, followed by post hoc by Fisher's exact test.[47] Comparisons (pair-wise) of failure modes between groups were conducted (alpha=0.05). Associations between failure modes and type of dentin treatment were examined by Pearson's chi-square test.[47]

Results

Eight specimens failed in preparation (Group 1=2 failed specimens of 23; Group 2=3 of 23; Group 3=3 of 23), due to composite rod fracture during tube removal or in handling. All failed specimens showed adhesive failure. Sixty-one specimens (Group 1=21; Group 2=20; Group 3=20) were then available for testing.

The mean (±SD) bond strength (MPa) of resin composite was: 6.69 (±4.08) when bonded to Carisolv®-treated dentin (Group 1); 10.31 (±5.47) when bonded to rotary-instrumented dentin (Group 2); and 7.16 (±6.64) when bonded to noncarious dentin (Group 3; Table 1). Overall, the mean bond strengths of resin composite bonded to dentin in the 3 groups differed significantly (1-way ANOVA, F ratio=3.99, df=60, P=.02). There was no statistically significant difference between the mean bond strengths of resin composite bonded to Carisolv®-treated dentin (Group 1) and noncarious dentin (Group 3): 6.69 (±4.08) vs 7.16 (±6.64), respectively (Fisher's exact test, df=58, P=.80). The mean bond strength of resin composite bonded to rotary-instrumented dentin (Group 2) was significantly higher than that of resin composite bonded to Carisolv®-treated dentin (Group 1): 10.31 (±5.47) vs 6.69 (±4.08), respectively (Fisher's exact test, df=58, P=.02), and was also significantly higher than the mean bond strength of resin composite bonded to noncarious dentin (Group 3): 10.31 (±5.47) vs 7.16 (±6.64), respectively (Fisher's exact test, df=58, P=.01).

Control specimens (Group 3) were approximately twice as likely to fail in adhesion than those treated with Carisolv® (Group 1), or rotary instrumentation (Group 2): 60% vs 29% and 30% respectively (Table 2). Groups 1 and 2 were more likely to show mixed failure (38% and 55%, respectively). Few specimens showed cohesive failure in dentin (14%, 5%, 10%). The Carisolv® group was 2 to 4 times more likely to fail cohesively in resin than rotary-treated or control groups (19% vs 10%, and 5% respectively). No association was seen between failure mode and treatment type (chi-square=8.25, df=6, P=.22). Specimens were classified by failure mode, and the mean bond strengths were calculated; no statistically significant relationship was seen (1-way ANOVA, F ratio=0.92, df=60, P=.44; not tabulated).

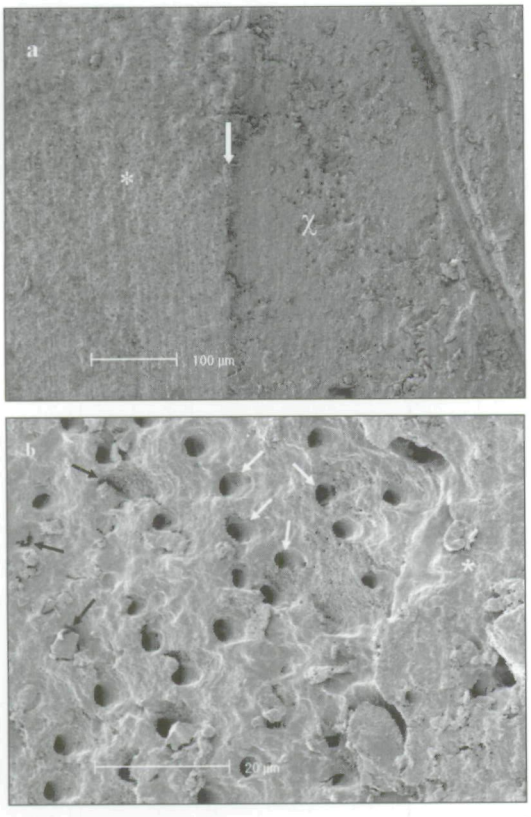

Figure 1. (a) Image of margin (white arrow) between bonded (χ) and nonbonded (*) Carisolv®-treated dentin. (b) Carisolv®-treated dentin showing predominantly patent tubule orifices (white arrows) and cutting debris (*) partially occluding some tubule orifices (black arrows).

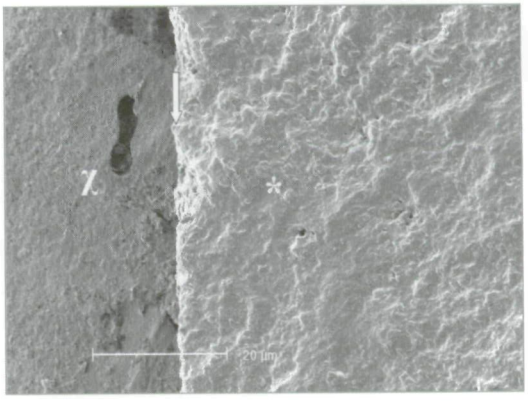

Figure 2. Image of margin (white arrow) between bonded and non-bonded rotary-treated dentin showing a resin-impregnated dentinal surface (*) adjacent to rotary-treated dentin with extensive smear layer (χ).

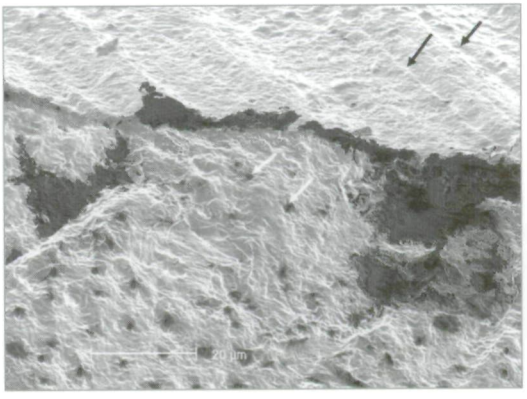

Figure 3. Dentin in a control specimen showing smear layer and striations due to saw blade cutting (black arrows) and predominantly patent dentinal tubules (white arrows).

Prepared dentinal surfaces adjacent to bonded areas were viewed under SEM; the surfaces of Carisolv®-treated dentin and untreated dentin appeared similar (Figure 1a). The Carisolv®-treated dentin showed bur-cuts, little or no smear layer, dissolved intertubular dentin, predominantly patent tubules, and intact peritubular dentin (Figure 1b). Attempting a sample estimation of the extent to which smear plugs occluded tubules, only 16 of 102 (15%) tubule orifices in 6 consecutive fields of 1 specimen (3,200X magnification) were partially or completely occluded. Rotary instrumentation created an extensive smear layer containing porosities (Figure 2). Control specimens showed patent tubules, a smear layer, and saw cut striations (Figure 3).

A specimen with fractured adhesive, including small porosities, perhaps due to residual ethanol solvent in the Single Bond, is shown in Figure 4a. A thin hybrid layer is seen at the resin-dentin interface in Figure 4b. Carisolv®-treated dentin showed globular defects and small porosities (Figure 4c); untreated dentin showed intertubular and peritubular dentin and predominantly patent tubules (Figure 4d). The dentin interface of rotary-instrumented specimens showed a wave-like smear layer with occluded tubules; deeper normal dentin showed predominantly patent tubule orifices (Figure 5). Control specimens showed an interface of normal dentin with saw-cut surface striations; predominantly patent tubules were seen in both longitudinal and cross sections deep to the adhesive surface (Figure 6a). A specimen with cohesive dentinal failure showed a surface devoid of adhesive layer (Figure 6b).

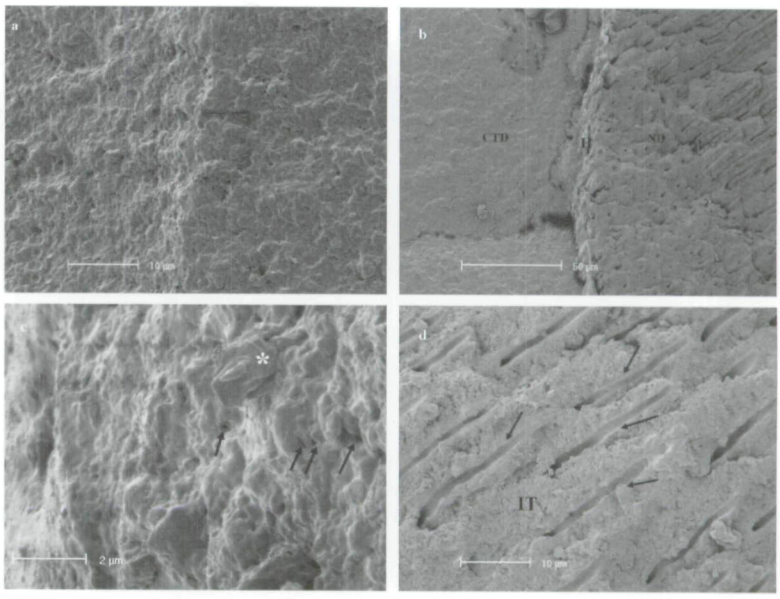

Figure 4. (a) Thick adhesive layer on Carisolv®-treated dentin showing fracture pattern and small porosities. (b) Interface between Carisolv®-treated dentin (CTD) adhesive and untreated dentin (ND) showing the intervening hybrid (H) layer. (c) Carisolv®-treated dentin adhesive at high magnification showing a globular defect (*) and small porosities (black arrows). (d) Longitudinal section of untreated dentin showing open dentinal tubules (black arrows) and surrounding intertubular dentin (IT).

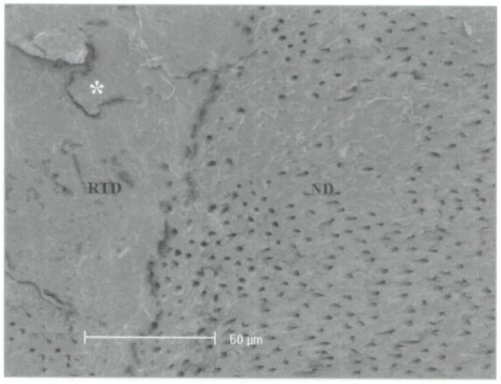

Figure 5. Interface between rotary-treated dentin (RTD) and untreated dentin (ND) showing cutting debris (*) and occluded dentinal tubules in treated dentin and predominantly patent tubules in untreated dentin.

Specimens with adhesive failure showed adhesive-impregnated dentin but no surface resin composite. Specimens with cohesive dentinal failure showed irregularly sheared dentin surfaces devoid of resin or adhesive layer. Specimens with cohesive failure in resin showed irregularly fractured resin covering the dentin-bonded surface. In mixed failure specimens, bonded areas showed some dentin devoid of resin composite and other areas with fractured dentin bonded to the surface. Of note, all specimens showed the resin composite had escaped from beneath the PVC tube during bonding.

Discussion

This laboratory study investigated the effect of Carisolv® treatment on dentinal adhesion in cariously affected primary molars. The lesions differed in extent, depth, location, and, therefore, in characteristics of dentinal tubules. Due to lack of suitable teeth, lesion sizes could not be matched across groups. Since the floor of the prepared cavity followed the lesion shape, a flat bonding surface could not always be achieved, resulting in resin composite escape beneath the PVC tube, which may have affected the observations.

Little is known of the effect of Carisolv® treatment of carious dentin in primary molars on resin adhesion. The influence of Carisolv® on resin adhesion has been studied, using sound buccal surfaces of primary molars and premolars and 2 adhesive/resin composite systems: Clearfil SE/Clearfil APX (Kuraray, New York, NY) and Single Bond/Z250 (3M).[43] Carisolv® significantly reduced the mean microshear bond strength (MPa) of resin adhesion to sound primary dentin (27.8-19.2), but the mean microshear bond strength of resin adhesion to sound permanent dentin was unaffected (Carisolv® with or without Clearfil SE/Clearfil APX=21.7 and 21.3, respectively; Carisolv® with or without Single Bond/Z250=7.6 and 6.7, respectively).[43] The mean microshear values (MPa) observed in the present study were lower (Carisolv® treatment=6.69; rotary instrumentation=10.31; noncarious dentin=7.16) than those observed by Hosoya et al.,[43] for sound primary dentin. The present findings also differed in that Carisolv® treatment had no effect on dentinal bond strength.

The differing findings may reflect several factors. Bond strength values depend on: laboratory equipment and instrumentation; reflecting specimen geometry; sample preparation and surface area; storage protocols; strain rate used to debond specimens; and operator variability. In contrast to previous studies performed on caries-free dentin treated with Carisolv®, the present study used carious specimens. In the study by Hosoya et al., the specimens were ground with a water-cooled air turbine and a diamond bur, then abraded with wet silicon carbide papers to expose dentin between the dento-enamel junction and the pulp chamber wall.[43]

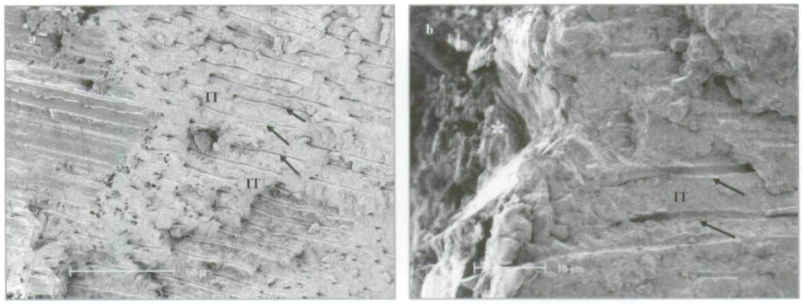

Figure 6. (a) Untreated dentin showing patent tubules (black arrows), surrounding intertubular dentin (IT), and surface smear layer. (b) Untreated dentin showing cohesive failure in dentin with the surface devoid of resin, adhesive layer (*), patent tubules (black arrows), and surrounding intertubular dentin (IT).

Specimens in the present study were prepared by removing the caries, resulting in a relatively flat floor rather than a ground and polished flat surface. Whereas previous studies have used a blade for shear bond strength testing, a wire loop was used in the present study—an approach yet to be investigated fully to determine its effect on bond strength values.[38,43] Delivering a shear force via a loop is thought to concentrate the force at the interface, allowing distribution of stresses. In a blade test, the stress is concentrated at the specimen contact point and may not be applied uniformly to the adhesive.[48] The large standard deviations seen in the present bond strength values may also reflect specimen variability, direction of dentinal tubules, small sample size, and technique sensitivity.[49]

The dominant failure modes in the present study were mixed failure in the Carisolv® (38%) and rotary-instrumented groups (55%), and adhesive in the control group (60%). The study of Hosaya et al.,[43] also reported predominantly mixed failures affecting approximately 88% and 75% respectively, of the Carisolv® and control groups. An in vitro study of permanent molars found adhesive failure abundant in both Carisolv® and rotary-instrumentated groups.[38] The lack of correlation in shear bond strength between failure mode and treatment type seen in the present study supports observations of others,[37,43] suggesting that failure mode may relate more to the restorative material than treatment type. The higher incidence of cohesive dentinal failure in the Carisolv® group (~14%), approximately 3 times that of the rotary group (5%), may indicate structural weakening of the dentin surface by Carisolv®.

The relationship between Carisolv® and the smear layer is unclear. It is unknown whether Carisolv® treatment prevents smear layer formation or whether a smear layer is produced during the scraping of carious dentin, which Carisolv® treatment then removes, leaving patent dentinal tubules. An in vitro study of the effect of 3-minute Carisolv® treatment on primary and permanent healthy dentin has shown complete removal of the smear layer from primary tooth dentin, leaving patent dentinal tubules and smooth intertubular dentin; in permanent tooth dentin, smear layer remnants partially occluded, the tubules, and roughened intertubular dentin was noted.[39] The authors concluded that Carisolv® was more effective in removing the smear layer and smear plugs in primary dentin than in permanent dentin.[39]

In the present study, Carisolv® removed the smear layer after instrumentation, leaving open dentinal tubules. This may be due to the high pH of Carisolv® gel or to dissolution by the concentrated sodium hypochlorite.[1] In the present study, an estimate of smear plug formation was attempted by counting occluded tubules; in a series of 6 consecutive fields in a representative specimen examined under 3,200X magnification, only 15% (16 of 102) dentinal tubule orifices were partially or completely occluded. It was concluded that Carisolv® treatment either removed the smear layer or prevented its formation during instrumentation. This supports the findings of previous studies conducted on primary tooth dentin,[1,28,39] but contradicted studies on permanent dentin where Carisolv® left a smear layer occluding tubules similar to that seen following rotary instrumentation.[30-32,48] The differing observations may indicate a higher susceptibility of primary dentin to Carisolv® than permanent dentin, given the differences in structure, mineral content and morphology between the 2 dentin types.[43,49,50]

The rotary-instrumented dentinal surface showed an extensive, wavelike smear layer covering the entire surface, consistent with use of a round bur, which occluded dentinal tubules with plugs and masked the surface characteristics of normal dentin. The nature of the prepared dentinal surface contributes to the bonding of adhesive restorative materials. To achieve adequate bonding, the occlusive smear layer which limits resin penetration into the collagen network of the intertubular dentin must be removed or treated by briefly etching the dentin surface.[26,27]

In the present study, the residual surface after Carisolv® treatment appeared ready for bonding and devoid of smear layer in contrast to the rotary-instrumented dentin. The microshear bond strength of resin composite bonded to Carisolv®-treated dentin, however, was lower than that bonded to rotary-instrumented dentin. This may be due to the effect of Carisolv® on the underlying dentin, as Carisolv® treatment is known to preserve most of the caries-affected dentin, leaving a thick demineralized area of collagen network of 3.5 to 4.5 μm.[29,48] Etching this dentin increases the demineralization depth to 7 to 8 μm,[29,48] which may result in a thick hybrid layer with the deepest demineralized dentin not fully resin-infiltrated, thereby reducing the bond strength of the resin composite. This possibility has also

been used to explain the nanoleakage phenomenon noted in Carisolv®-treated specimens.[49]

The Carisolv® gel used in the present study was a new clear gel with a reduced concentration of amino acids and a higher concentration of sodium hypochlorite (0.95%) than in the previous formulation. The recent change in the formulation of Carisolv® could explain why the shear bond strength values in the present study were lower than those found in previous studies.[43] Clinically, the modified product has reduced treatment time, but the effect of the higher sodium hypochlorite concentration on dentin and demineralization depth is unknown.[22] Images observed under SEM in the present study showed wide areas of demineralization in the Carisolv®-treated specimens of up to 200 μm. The resin material fails to infiltrate such deep areas, and this contributes to the low values of shear bond strength of resin composite to Carisolv®-treated dentin, as shown by the lack of statistically significant differences from the control group.

In the present study, chemomechanical caries removal with Carisolv® was effective. No adverse effect of Carisolv® on bond strength of resin composite was seen in comparison with sound dentin. The results need independent confirmation before generalization. Using a flowable resin composite may improve resin infiltration into deeper demineralized areas and may provide higher bond strength values than seen in the present study.

Conclusions

Based on this study's results, the following conclusions can be made:

1. The microshear bond strengths of resin composite bonded to Carisolv®-treated carious dentin did not differ significantly from that of resin composite bonded to noncarious dentin, but were significantly lower than that of resin composite bonded to rotary-instrumented carious dentin.
2. The modes of failure of resin composite were mixed following Carisolv® treatment and rotary instrumentation, and an adhesive mode of failure following bonding to noncarious dentin.
3. The smear layer was either removed by Carisolv® or precluded from forming during hand instrumentation.
4. The modified Carisolv® gel formulation with 0.95% sodium hypochlorite produced deep demineralization with incomplete infiltration of resin composite into the collagen network.

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